3. The probable variation of the values is conveniently small.

4. The probable variation when converted into units of pressure, gives an accuracy of reduction which is very satisfactory, even for long air columns.

ACKNOWLEDGMENTS.

My thanks are due to Dr. Charles F. Brooks, who, through the several months I have been studying the problem, has been a willing advisor, a prolific source of ideas and suggestions, and a patient listener; also, to Mr. Willis Ray Gregg, who has shown an encouraging interest in the project, has given helpful suggestions, and who has supplied me with aerological data. I am grateful to Prof. Charles F. Marvin for conferences in which he not only assisted me on some of the statistical points but showed a stimulating interest in the problem; and to Dr. W. J. Humphreys, who has never been too busy to discuss the work as it progressed.

TEMPERATURES VERSUS PRESSURES AS DETERMINANTS OF WINDS ALOFT.[1]

By W. R. GREGG, WEATHER BUREAU.

[Author's Abstract.]

From theoretical considerations a certain definite relation is expected to exist between the pressure gradient indicated on synoptic weather maps and the wind at a short distance, some four or five hundred meters, above the surface. Observations with kites and balloons show that this relation does exist, when averages are considered, but that wide variations are frequently found in individual cases. These variations are due partly to incorrect sea-level pressure reductions, partly to too much smoothing of the isobars, but principally to departures of horizontal temperature distribution from normal conditions. If, for example, there is a steep latitudinal temperature gradient, the free-air winds quickly depart from those indicated by the pressure gradient, and the principle of "gradient winds" breaks down. If, on the other hand, there is little temperature change over extended areas, the free-air winds conform very closely to the surface pressure distribution and indeed under these conditions anticyclones and cyclones are found to continue as such to great altitudes. The first type is most frequently found in winter and the second in summer, but occasionally in other seasons; in all cases it is the temperature distribution that is the controlling factor. Two illustrations are given: One shows the conditions on December 17, 1919, when a very steep south to north temperature gradient produced over the entire country, east of the Rocky Mountains, free-air west-northwesterly winds, quite at variance in many sections with the surface pressure distribution. (A note on this appeared in the MONTHLY WEATHER REVIEW, Dec. 1919, **47**: 853–854.) The other illustration shows the conditions on March 23, 1920, when absence of any marked latitudinal temperature gradient resulted in free-air winds closely following the surface isobars to heights of 4 to 8 kilometers.

Studies based upon observations in Europe indicate that anticyclones are warmer than cyclones at all levels in the troposphere. In the United States the reverse condition has been found. The reason for this difference is not that different processes are in operation, but that in Europe the effects of purely dynamic heating and cooling are more pronounced than are those due to the importation of cold and warm air by winds with a northerly or southerly component, whereas the reverse is true in the United States. The free-air pressure gradients resulting from changes in air density due to these currents of warm and cold air are decidedly different from those at sea-level and show that LOWS bend backward with altitude to the northwest and HIGHS to the southwest. Hence, in the upper levels winds with a northerly component (usually northwesterly) blow across the surface HIGHS, and winds with a southerly component (usually southwesterly) across the surface LOWS. These are average conditions. Variations from them are of course produced by variations in surface and free-air temperatures from the normal. A careful study of these temperature variations gives valuable aid not only in forecasting free-air winds, but also in predicting the movements of cyclones and anticyclones, and therefore the accompanying changes in surface conditions.

[1] Presented before American Meteorological Society, Washington, D. C., Apr. 22, 1920.

DETECTION OF STORMS AND THEIR TRAVEL BY RADIO EQUIPMENT.

By Lieut. (j. g.) C. N. KEYSER.

[Navy Department, Washington, D. C., June 18, 1920.]

The perfection of radio apparatus for securing compass bearings by ships and aircraft paves the way for the development of a new phase of meteorological forecasting. The question of static has been the subject of considerable investigation by those interested in radio transmission as well as those interested primarily in meteorology and meteorological prognostication. Those interested in radio attacked the problem, first, in respect to its elimination from the field of radio transmission as a whole, and later, when this failed, in respect to the elimination of this interference from the radio receiver itself. The first problem resolved itself into finding out during what periods, in what particular localities, and under what conditions static disturbances prevented or hindered the receipt of radio messages, in order that times of transmission and locations for stations might be determined upon to eliminate this difficulty. These attempts at eliminating static did not prove successful. As a result the next attempt was made to eliminate static interference from the receiving set itself, and in this much greater progress has been made. The latest developments in radio receiving equipment have been successful in damping considerably, if not entirely eliminating, the interference from static disturbances.

The problem, from the meteorologist's standpoint, is not to devise means of eliminating static from radio receiving, but to associate the various types and intensities of static with the approach, movement, and intensity of local and general electrical storm, and of forecasting the approach of the same. The advent of aviation, more especially of "lighter-than-air" craft has made the forecasting of this type of storm of vital importance.

The matter of detecting storms in their travel by the use of radio equipment is still in its experimental stage and is as yet an open field for the experimenter as well as the amateur meteorological and radio enthusiast to enter. The time will probably come when storm detectors will be a part of the regular equipment of all meteorological stations, and when the reporting of static will be an important part, during certain seasons, of all meteorological reporting services.

Some original and important experimental work along this line has been carried on by Lieut. W. F. Reed, U. S. N., aerological officer of the naval air station, Pensacola, Fla.[1] Lieut. Reed has been successful by the use of a radio receiver and direction finder to forecast the approach and movement of electrical disturbances over that particular portion of the Gulf covered by aviation operations from the Pensacola base. He has been able to detect the approach of these storms long before any local signs give warning of their approach and has been able to plot the movement of these storms, the directions from and to which they are moving, as well as their intensity. By this means he has been able to make the aviation operations from this base safer and much more successful. During the coming hurricane season it is to be hoped that this station, as well as others, may be able to carry on some extremely valuable experimental work, which in time may lead to the use of radio as a valuable aid to the hurricane-reporting service in the Gulf and Caribbean.

The field is large and there is need for considerable experimental work on the part of meteorologists acquainted and in touch with radio work. Our present forecasts of probability of the formation and approach of electrical disturbances and rather indefinite notice of their movements should in time be superseded by forecasts of a more definite nature, telling when to expect the disturbances at certain points, the direction and rate of movement, and their intensity. This type of service is at present rendered on a large scale in so far as the West Indian hurricanes are concerned, but in the case of nearly every one of these storms the position of their centers and the direction and rate of their movement is unknown for many hours, and in many cases days, by the forecasters who are charged with the task of reporting them, due to a lack of reporting stations over great areas of the Gulf and Caribbean during the progress of the storm. On the first notice of their formation and approach most vessels strike for port. Radio equipment, in addition to the broadened program of aerological observation, tide reports, and perhaps even vessel patrols now planned by the Weather Bureau, may in time fill this gap.

[1] Further details of Lieut. Reed's work will appear in a later issue of the REVIEW.

AEROLOGICAL OBSERVATIONS IN THE WEST INDIES.

It is generally thought that tropical cyclones (hurricanes) move approximately in the direction and with the speed of the air in the strata at no great height above the surface. If this be true, it is very desirable to obtain observations of free-air wind conditions on all sides of hurricanes, particularly on the north and west sides. Although working under severe restrictions of funds and personnel, the Weather Bureau is undertaking a campaign of this sort for the hurricane season of 1920, July to November, inclusive. Stations are being equipped and will be operated at San Juan, P. R., and Key West, Fla., in addition to those in the Gulf States at which observations are now being made by the Weather Bureau at Groesbeck, Tex., and Leesburg, Ga.; by the Meteorological Section of the Signal Corps at Ellington Field and Kelly Field, Tex.; and by the Naval Aerological Section at Pensacola, Fla. Moreover, two new stations are being organized by the Navy at Colon and Santo Domingo. These nine stations form a network which, it is believed, will furnish information of great value in the study of these destructive storms and in forecasting their direction and rate of movement. Moreover, the observations will be taken regularly twice each day, irrespective of the occurrence of hurricanes, and will, therefore, give us data as to trades, antitrades, etc., of the utmost interest from a theoretical point of view and of inestimable benefit in their practical application. It is probable that some of the stations will be continued throughout the year and that many others will be added, if funds permit, during the next two or three years.—*W. R. Gregg.*

THE MEASUREMENT OF TEMPERATURE, WITH SOME REMARKS ON OTHER PHYSICAL MEASUREMENTS, AND APPLICATIONS TO METEOROLOGY.[a]

By EDGAR W. WOOLARD.

INTRODUCTION—UNITS IN GENERAL.

Lord Kelvin once wrote, "When you can measure what you are speaking about and express it in numbers, you know something about it, and when you can not measure it, when you can not express it in numbers, your knowledge is of a meager and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thought advanced to the stage of a science."

The general Theory of Measurements is familiar to everyone: There are five *fundamentally* different entities which physics is at present considering, viz, those the *concepts* of which are symbolized by the words *space, time, matter, electricity,* and *entropy.*[1] Hence, as was pointed out by Rucker,[2] we need five *fundamental units* for the measurement of physical quantities; those usually chosen are the units of length, mass, time, permeability, and temperature, although better selections probably could be, and have been, made.[3] However, it has been found that by arbitrarily fixing the magnitudes of the units corresponding to the three indefinables of mechanics—space, time, and matter—we are then enabled, through the Theory of Dimensions, to derive units for all other quantities. In a few cases, such as when dealing with heat and electricity, additional units which are sometimes called *secondary* fundamental units appear, but probably it is only our ignorance of the true nature of the quantities involved which prevents us from expressing these, too, in terms of the three primary fundamental units.[4]

The practical application of the above theory consists of the selection of the fundamental units, the construction of standards, and the devising of measuring instruments which may be calibrated by comparison with the standards.

[a] Delivered in part before Am. Metl. Soc., Apr. 22, 1920.

[1] These five concepts, together with that of *number*, are necessary and sufficient for the complete description of the universe so far as it is at present known to us from observation: the objective universe, however, is itself composed of only matter and energy—the other indefinables are not "things," strictly speaking, but only creations of the mind, *conventional frames imposed on the universe* for convenience in study and interpretation. *Cf.* H. Poincare: Foundations of Science: and K. Pearson: Grammar of Science.

[2] A. W. Rucker: On the suppressed dimensions of physical quantities. Phil. Mag., (5), 27, 104–114, 1889.

[3] See, *e. g.*, R. C. Tolman: The measurable quantities of physics. *Phys. Rev.*, (2), 9, 237-253, 1917.

[4] W. Watson: Textbook of Physics, new ed. London, 1911, pp. 5, 334; Rucker, *op. cit.*